Chapter 4
A Global View on Future Major Water Engineering Projects

Klement Tockner, Emily S. Bernhardt, Anna Koska, and Christiane Zarfl

Abstract Human activities have altered how the world functions. During the past decades, we have globally, fundamentally, in the long-term, and in most cases irreversibly modified all spheres of earth. This new epoch, often referred to as the Anthropocene, is just in its early stages. Indeed, there is general agreement that the transformation of our globe takes speed, with consequences that we can hardly imagine but that may threaten our own survival. This goes along with the general idea that major infrastructure projects are a sign of technological progress and believed to stimulate economic development and to improve living conditions for humans. In the present essay, a representative inventory of future major engineering projects, either planned or under construction in aquatic systems worldwide, shows that the rapid transformations of the Anthropocene are particularly evident in the freshwater domain. Worldwide examples of very large dams, major interbasin water-transfer and navigation projects, as well as large-scale restoration schemes, underline the dimensions of and the challenges associated with future megaprojects that will change our freshwater environment. Opportunities to mitigate the consequences of megaprojects based on the lessons learnt from projects in other infrastructure sectors range from ecological engineering to smart water investments that are adjusted to the respective national, social, economic, and environmental conditions.

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4.1 Introduction

"Welcome to the Anthropocene", entitled *The Economist* on 21 May 2011. The Anthropocene indicates a geological epoch that follows the Holocene. Since the beginning of the industrial revolution, human activities have altered how the world functions. We have globally, fundamentally, in the long-term, and in most cases irreversibly modified the geosphere, hydrosphere, atmosphere and particularly the biosphere (Steffen et al. 2011; Rockström et al. 2014). And we are just at the beginning of this new epoch. There is general agreement that the transformation of our globe takes speed, with consequences that may threaten our own survival. Indeed, we are probably not able to imagine, or at least it sounds like science fiction (e.g. Pendell 2010), which alterations we will face in the coming decades to centuries. This includes, for example, the widespread creation of synthetic organisms, the exploitation of the ocean floor, the large-scale loss of coastal areas, the collapse of deltas, and a 4–8 °C warmer globe. We urgently need to understand the future dimension of this epoch and the consequences for the environment and the humans alike. And we need to consider fundamentally new strategies on how to cope with the immense challenges we are facing.

"Terraforming", i.e. the remaking of the earth surface, is not science fiction. Indeed, it is taking gear too. In China, for example, whole mountain ranges are levelled off to create space for new cities (Li et al. 2009). Mining activities reshape increasingly the earth surface because of an increasing demand for minerals and the concurrent depletion of resources. We dry-up entire river basins, truncate the global fluvial sediment transport, alter the global biogeochemical cycles and transform forests, steppes and deserts for crop and biomass production (e.g. Hooke and Martín-Duque 2012, Table 1). Terraforming not only requires land but also consumes huge amounts of energy and water.

At the same time, our planet is facing a major water crisis. Population growth and economic development are strongly increasing the global freshwater demand, while climate change further exacerbates the uneven distribution of water. The water crisis is spreading through all sectors, from sanitation, drinking water supply, agriculture and energy. Therefore, the signals of the Anthropocene are particularly evident in the freshwater domain (Table 4.1). Nutrient enrichment, exploitation of fossil groundwater reservoirs, fragmentation of river networks, alteration of the flow, sediment and thermal regimes, shrinking deltas and the accelerating erosion of freshwater biodiversity are clear signs of the rapid transformation of aquatic systems.

The water sector represents an immense market and the projected global expenditure on water and waste-water services is steadily increasing: from USD 576

Table 4.1 Signs of the Anthropocene in freshwater systems

		Pressures	Status and projection	References
Geosphere	Delta regions	Reduced sediment input, increasing subsidence rate, salinisation, sea water rise, demographic pressure (e.g., actually 500 million people live in deltas)	Surface area vulnerable to flooding may increase by 50 % in twenty-first century.	Syvitski et al. (2009) and Giosan et al. (2014)
			Several deltas (e.g. Indus, Ganges) are facing complete collapse in near future	
	Sediment balance	Retention behind dams, land-use change, soil erosion	100 billion metric tons of sediments and 1–3 billion metric tons of C sequestered in reservoirs (status 2005); storage may double within the coming decades due to a boom in dam construction	Syvitski et al. (2005) and Zarfl et al. (2015)
	Coastal regions	Nutrient input, climate change	Exponential increase of dead zones (oxygen-depleted regions) since the 1960s; today about 400 coastal dead zones cover more than 245,000 km^2	Diaz and Rosenberg (2008)
Hydrosphere	River flow	Climate change, water abstraction, land-use change, damming, interbasin transfer	Increase in extreme events, rapid expansion of temporary streams, widespread change of flow regimes	Nilsson et al. (2005), Vörösmarty et al. (2010), and Acuña et al. (2014)
	Groundwater	Exploitation for irrigation, demographic development, climate change, pollution	From 1960 until today, groundwater depletion increased from 126 ± 32 to 283 ± 40 $km^3\ a^{-1}$ (India, USA, Pakistan, China and India jointly share 71 % of global groundwater withdrawal)	Giordano (2009) and Wada et al. (2010)
	Water quality	Urbanisation, agriculture intensification, industry, synthetic substances	Worldwide contamination of freshwater systems with thousands of industrial and natural chemical compounds, eutrophication	Camargo and Alonso (2006), Schwarzenbach et al. (2006), and Vörösmarty et al. (2010)
Biosphere	Biodiversity	Habitat degradation, flow regulation, pollution, climate change, invasion	10–20,000 freshwater species are estimated extinct or imperiled;	Strayer (2006) and WWF (2014)
			Freshwater vertebrate populations declined by 73 % between 1970 and today;	
			63 % of all freshwater megafauna species listed as threatened	
	Ecological novelty	Species invasion, novel stressors	Faunal homogenisation, emerging pathogens, GMOs and synthetic organisms	Jeschke et al. (2013)
Atmosphere	Global carbon cycle	Pollution, habitat degradation, damming	Increased greenhouse gas emissions from near-natural, altered, and artificial freshwaters	Wehrli (2011), Raymond et al. (2013) and Zarfl et al. (2015)

billion in 2006, to USD 772 billion in 2015, to USD 1,038 billion in 2025 (Ashley and Cashman 2006). And the projected expenditure on water infrastructure as percentage of GDP will increase too, from 0.75 % in 2015 to more than 1 % in 2025. These values do not include the major water engineering projects that are either planned or under construction. For example, the construction of 3,700 future hydropower dams may require an investment of about USD 2 trillion, excluding operation costs as well as the costs caused by social and environmental damages (Zarfl et al. 2015). A primary challenge in designing and operating major water infrastructure projects will be to balance the economic benefits while preventing social costs and the loss of natural ecosystem services.

In this chapter, we provide a comprehensive albeit in no case complete inventory of future major engineering projects, so-called megaprojects, that are either planned or under construction in freshwater systems worldwide. We focus on very large dams, major interbasin water-transfer and navigation projects, as well as on large-scale restoration schemes. The main goal is to raise awareness about the dimension of and the challenges associated with future megaprojects. We discuss opportunities to mitigate the consequences of megaprojects based on the lessons learnt from projects in other infrastructure sectors.

4.2 Major Engineering Projects in the Water Sector

Major engineering projects are large-scale and complex projects that typically cost much more than USD 1 billion, require years to decades to be developed and constructed, affect large areas – very often across political and geographical boundaries, involve many public and private stakeholders, induce transformational processes, and may impact millions of people (Flyvbjerg 2014). In the water sector, such megaprojects encompass interbasin water-transfer projects, large-scale wetland drainage and irrigation schemes, navigation canals, drinking water facilities and sewage treatment plants for large cities, large dams, flood control and coastal protection measures, and major restoration schemes (Table 4.2). Furthermore, many small engineering projects may have cumulative effects that are similar to the effects caused by individual megaprojects.

The monetary scale of the investment is often inversely correlated with the potential for future adaptation and modification. Indeed, the lifespan of major water infrastructure projects is a century, and more, therefore new ideas and creativity now get “fixed”. It means that the decisions we make now will heavily constrain the options we will have later.

4.2.1 Interbasin Water-Transfer Projects

Interbasin transfer projects (IBTs) are considered as an approved engineering solution meeting the accelerating demands for water to secure food production, support economic development and reduce poverty. To compensate for the increasingly

Table 4.2 Selected major water engineering projects globally (name, type, expected construction costs, planned construction time, short description and potential consequences)

Project	Type	Brief description	Costs [billion USD]	Timeline	(Environmental) Impacts	References
Nicaragua Canal *Nicaragua*	Navigation	286 km long navigation canal (90 km through Lake Nicaragua), 27.6 m deep, 520 m wide	40	2015-	Relocation of indigenous people (hundreds of villages); no environmental feasibility study released so far, but impacts expected on Lake Nicaragua (salt intrusion, sedimentation, invasive species, pollution) and destruction of around 400,000 ha of pristine rainforests and wetlands	Meyer and Huete-Pérez (2014)
Emergency Water Transfer Project (Tarim River Restoration Project) *China*	Restoration/ transfer	Artificial canal to divert water (annual average: 320×10^6 m^3) from Lake Bostan and the Daxihaizi Reservoir to the Tarim River	1.3	2000–2006	Transfers depend on the hydrological condition of the Kaidn-Konqui River system (Bostan Lake); ecosystem integrity strengthened	Li et al. (2009), Zhang et al. (2010), and Sun et al. (2011)

(continued)

Table 4.2 (continued)

Project	Type	Brief description	Costs [billion USD]	Timeline	(Environmental) Impacts	References
Grand Melen Project *Turkey*	Transfer	water transfer from Grand Melen Stream to Istanbul through a 180 km long transmission line; annually 268×10^6 m^3 at Stage I, 1.18×10^9 m^3 total at Stage IV	2.15	Stage I finalised in 2011	One town and 16 villages are expected to be covered by water with the project	WWF Germany (2008)
Lesotho Highlands Water Project *Lesotho/South Africa*	Transfer	five dams and about 200 km of tunnels; transfer of water from Orange/Senqu River (Lesotho) to Vaal River (South Africa) ~ $2,000 \times 10^6$ m^3 per year	8	1986–2020	displacement of 17 villages, loss of agricultural land for 71 villages, and degradation of water quality; began without an environmental impact assessment for the overall project	WWF Global Freshwater Programme (2007)
The Bay Delta Conservation Plan *USA*	Transfer/ restoration	two tunnels, each 40 ft high and 35 miles long, under the Sacramento-San Joaquin River Delta	25	Construction start in 2017	could decrease fresh water flows to San Francisco Bay, could harm endangered fish in a different part of the estuary, will permanently transform the Delta	California Department of Water Resources (2014) and Safe the Bay (2014)

Emscher River Master Plan *Germany*	Restoration	A 30-year regional regeneration program involves water quality improvements and physical rehabilitation of the river network	4.4	Restoration start in 1991	Once an open sewer in one of the most populated areas in Europe, the catchment of the Emscher River is one of the most ambitious restoration projects actually carried out in Germany	Schwarze-Rodrian and Bauer (2005)
Restoration and remediation of coal mining areas *Germany*	Restoration	Avoidance and source treatment, natural attenuation of acidity loads, remediation in constructed wetlands and underground treatment, in-lake and outflow treatments	9 (during the past 20 years)	Restoration of coal mining areas	The restoration of open-cast mining areas in Germany, as well as in Poland and other countries, is a long-lasting task because the large areas affected, delay effects, and the challenge to combine geo-engineering with ecological engineering approaches. Formation of novel ecosystems and communities.	Geller et al. (2013)

uneven distribution of water, IBTs are regaining popularity (WWF Global Freshwater Programme 2007). However, many of the IBTs either planned or under construction are too big and complex to imagine their consequences, and they may distort the economic, social and environmental conditions of entire countries and regions. Donor and recipient systems will be affected alike.

The South-North Project in China, the Indian Rivers Linking Project, the Transaqua Project in Africa, the Sibaral Project in Central Asia and many more projects are at various stages of development and implementation. Projects that are in a very preliminary stage of planning may rapidly emerge and gain wide support when political and social circumstances change, or when major disasters occur (Table 4.2).

With the objective to provide water for more than 500 million people, the *South-North IBT* in China is one of the largest water engineering projects already under construction (Berkoff 2003). By 2050, about 45×10^9 m^3 water per year will be diverted through three branches from the Yangtze basin to northern and western China. The estimated costs are about USD 60 billion. The 1,264 km long Central Route was opened in 2014. 330,000 people were resettled. Moreover, plans exist for a much larger transfer project, namely to divert up to 200×10^9 m^3 water from the major rivers in SW China, including the upper sections of the Mekong, Brahmaputra and Salween Rivers, to the water-thirsty regions in northern and eastern China. This project is actually on halt because of the transboundary nature of the affected river basins.

The *Indian Rivers Linking Project (ILR)* might become the largest water infrastructure project ever undertaken globally (Shah et al. 2008; Bagla 2014). It is planned to build 30 links and about 300 reservoirs and to connect 37 Himalayan and Peninsular rivers to form a gigantic water grid system on the Indian subcontinent. The canals are 50–100 m wide and 6 m deep to allow navigation. In total, 178×10^9 m^3 water per year will be redistributed. For comparison, the annual discharge of the Rhine River at its mouth is 75×10^9 m^3. The total length of the planned canal network is 15,000 km, 30 million ha of newly irrigated area are expected to be created, and 35 GW hydropower should be produced (although a significant proportion of the energy will be required for the transfer of the water). The costs at this stage can only be estimated to amount three times the total costs of China's South-North water-transfer scheme.

Transaqua, the largest water infrastructure project planned in Africa, is intended to divert 100×10^9 m^3 (in average 3,200 m^3/s) from the Congo Basin, through a 2,400 km navigable canal, to the Chari River and finally to Lake Chad. It is intended to stabilise the lake area at about 7,500 km^2 and create large irrigation areas north of the lake. Planning dates back to the late 1970s. Actually, the project re-emerges to the surface. The estimated costs are USD 23 billion. An alternative and much smaller option, the Obangi Water-Transfer Project, is expected to transfer 320 m^3/s to Lake Tschad (Freeman and DeToy 2014). Up to now, no feasibility study has been carried out. However, there exists hope that the Chinese, within the frame of their Silk Road Fund, may invest into this project.

The almost complete drying of the Aral Sea is one of the largest global environmental disasters. Ideas to divert water from Siberia to Central Asia already emerged during the Tzarist period in the late nineteenth century. The concrete planning of the

Sibaral Project (from Siberia to Aral Sea), together with plans to nourish the Volga River through a transfer from western Siberian rivers, started during the Soviet era, but had been abruptly stopped in 1986 by Michael Gorbachev. More recently, it is enjoying again favour among various actors in Central Asia and in Russia as well. The archived construction plans for the 2,540 km long Sibaral canal are actually unearthed from the various institutes previously involved in the planning (Micklin 1977; Pearce 2009; Singh 2012). Sibaral is an example where the consequences of poor catchment management are expected to be solved through an immense engineering megaproject, which again is associated with probably very high economic, social, and environmental risks and costs, although a calculation of the costs and risks must remain a very rough estimate at this stage.

For North America, at least 15 separate projects have been proposed but not (yet) realised during the past century to reshape the continental water courses (Forest and Forest 2012). The most popular and ambitious proposal has been the *North American Water and Power Alliance (NAWAPA)*, which would have reconfigured the water courses through dams, canals, pipelines, etc. It is very hard to imagine the dimensions of this project (e.g. Barr 1975; Micklin 1977). It has been proposed to divert 20 % of the flow from the northern rivers, mainly from the Peace and Yukon rivers in Alaska and British Columbia, southward to a huge, 800 km long excavation called the Rocky Mountain Trench. From there, water would be diverted to the Great Lakes, to SW USA and finally to Mexico. The annual volume of water provided could be up to 300×10^9 m^3 per year, the estimated costs are between USD 420 billion and USD 1.4 trillion, and three million jobs are projected to be created. The concept had been called "grand and imaginative" (Abelson 1965), while Luton (1965) replied: "[…] let us wait until we know our doom is at hand, and when our last realisable ambition is to amaze future archeologists".

For a long time, plans have existed in *Australia* to move water from the water-rich northern areas to the southern parts of the continent (e.g., Kimberley to Perth Scheme, Bradfield Scheme, South-East Queensland water grid). However, local solutions such as improved use efficiency, recycling of water, desalinisation and reduced consumption prove to be economically, socially and environmentally much more sustainable than the long-distance transfer of water (Australian Government 2010).

Sudan and Egypt jointly began the construction of the *Jonglei Canal* in the 1970s (Salman 2011). The canal was meant to increase the downstream flow of the Nile waters by diverting water away from the vast wetlands where a high proportion of water is lost by evapotranspiration. The project, which was funded to a large extent by the World Bank, stopped in 1983 at about 100 km short of completion when the civil war between North and South Sudan started.

There are several other large-scale projects in the planning and construction phase throughout the African continent, including projects in Botswana, Namibia Lesotho, Morocco and other areas. Similar projects exist for southern Europe, Greece and Spain in particular, and for Turkey, but also for South America, in particular Brazil.

4.2.2 Navigable Waterways

The global navigable waterways encompass a network of 700,000 km that connects river basins across geographic regions. In the European Union, more than 50,000 km navigable rivers and canals create a dense web of waterways. Today, you may travel from southern France to western Siberia without entering the sea. Waterways facilitate the spreading of exotic and invasive organisms, which may lead to a homogenisation of freshwater biodiversity. Plans exist to upgrade and enlarge existing waterways, such as the Danube-Main-Rhine Waterway, and to create new waterways. At the same time, most of the planned interbasin transfer projects (Table 4.2) will support inland navigation too.

In South America, the 3,440 km Parana-Paraguay waterway, called *Hidrovia*, will connect Cáceres (Brazil) with Nueva Palmira (Uruguay). The main aim is to facilitate the export of soybeans, minerals, timber and other commodities from the interior. Extensive wetlands, in particular the Pantanal, will be affected by this project (Huszar et al. 1999; Gottgens et al. 2001). About 7.3×10^6 m^3 of sediment are dredged to enforce and straighten the rivers for navigation and to build ports. The calculated investment costs for a total of 88 individual projects are estimated at USD 4 billion (www.iirsa.org).

4.2.3 Hydropower Mega Dams

Currently, at least 161 very large hydropower dams, with a capacity of more than 1,000 MW each, are globally either under construction or planned. For illustration, a dam of 1,000 MW could, if to 100 % efficiently working, provide the annual electric consumption for 1.2 million people, assuming the electric consumption per capita in Germany in 2011 (World Bank 2014). This corresponds to sufficient energy to fully power a city almost as large and wealthy as Munich (2011: 1.38 million). The total capacity of the future mega dams amounts to 440 GW; most of the dams are planned in developing countries and emerging economies (Fig. 4.1), where consumption rates per capita are much lower than in Germany.

Not surprisingly, the global distribution of these future dams is not equal (Fig. 4.1). The largest number of large dams will be constructed in the Asian countries of China, Pakistan and Myanmar, in the South American countries of Brazil and Peru as well as the African countries of the Democratic Republic of Congo, Ethiopia and Nigeria.

What does this mean for the ecology? The Yangtze basin will be fragmented by the highest number of hydropower dams in Asia (33 % of the continental total). In South America, the Amazon basin will receive 61 % of the future hydropower dams of the continent providing 69 % of the planned capacity. And in Africa, mainly the Zambesi basin will be confronted with new dams (35 % of continental total) while the Grand Inga hydropower dam alone and planned in the Congo basin will provide 55 % of the capacity planned in Africa. The Yangtze and the Zambesi basins have already been classified as heavily fragmented, whereas the Amazon and the Congo

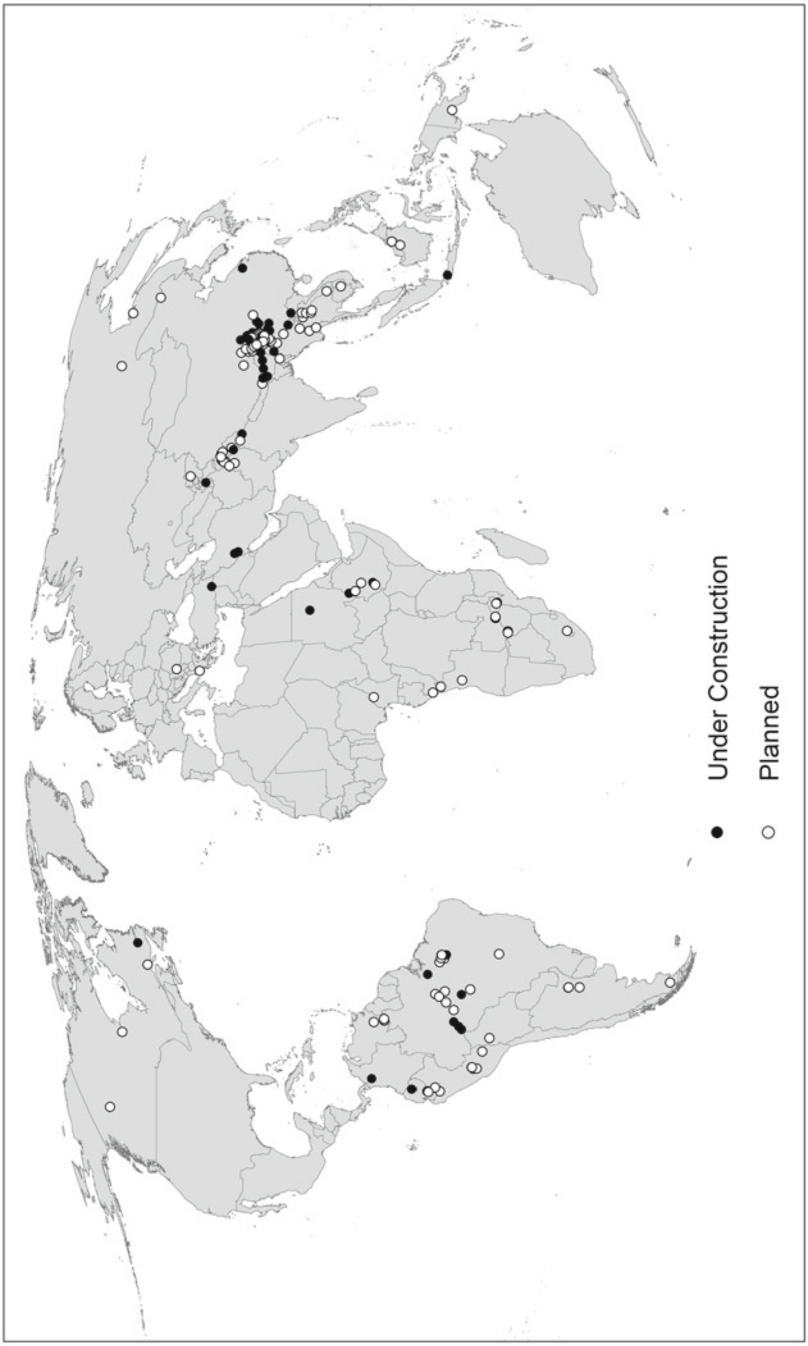

Fig. 4.1 Global distribution of future hydropower dams >1,000 MW that are under construction or planned, status 2014 (Data: Zarfl et al. (2015))

basins are among the moderately fragmented river systems (Nilsson et al. 2005). This means that these additional huge hydropower dams might change the fragmentation degree. There are also basins that have been classified as not fragmented so far that will face an increase in fragmentation, e.g. the Salween basin in Asia with 11 hydropower dams planned. Fragmentation leads to habitat destruction and prevents migration of aquatic organisms which might result in a decrease of biodiversity. In addition, hydropower dam operation will change discharge patterns, transport of sediments and water temperature.

For some of the "smaller" very large dams (1,000–2,000 MW) data on the size of the planned reservoir is known, which ranges up to 1,230 km^2 for the Mupata George in the Zambesi basin. This exceeds the size of Lake Yssel in the Netherlands and just indicates the area that might be required for huge hydropower dam constructions. One of the largest reservoirs by surface area, Lake Volta in Ghana, is flooding more than 8,500 km^2. This does not only affect the environment like flooding of terrestrial habitats, but also has social impacts due to the required relocation of the residential human population.

4.2.4 Large-Scale Restoration Projects

While major investments in new water redistribution and hydropower projects are underway across the emerging economies, governments throughout North America, Europe and Australia are devoting increasing efforts into removing or heavily modifying the major water infrastructure projects of the last century. Increasing recognition of the environmental harm to fisheries and biodiversity caused by hard infrastructure has spurred growing interest in dam removal and channel reconfiguration efforts to restore historic river structures and ecological processes.

As an inevitable consequence of increased environmental degradation and anticipated future environmental change, the demand for ecosystem restoration is rapidly increasing. "Develop now, clean-up later" has been the motto of many rapid emerging economies. The clean-up phase will be expensive and will take decades to centuries in most cases. Indeed, we probably are not able to imagine the future costs of ecosystem restoration, the damage in respect to loss of ecosystem services and the need to install extremely expensive engineering measures to compensate for the impacts of the past management decisions.

One of the most ambitious projects is the restoration of the *Mississippi River Delta*, following hurricane Katrina. It is planned to run for 50 years and estimated to cost between USD 500 million and USD 1.5 billion per year. And it will only stop future land loss, and not lead to the full recovery of the vast amount of wetlands already gone (Giosan et al. 2014). A recent study by Batker et al. (2010) shows that the investment to sustainably restore the Mississippi River Delta would return several time more of values in respect to provided ecosystem services. Indeed, the Mississippi River Delta Ecosystems provide economically valuable services, including hurricane storm protection, water supply, climate stability, food, furs, waste treatment, wildlife habitat, recreation and other benefits. These services are valued at USD 12–47 billion per year.

The *Comprehensive Everglades Restoration Plan* consists of over 68 civil works projects that will be implemented over a time period of 30 years. It will cost USD 8.3 billion, with the stated goals of improving water quality and reduced flooding of urban and agricultural areas. The main goal, however, is to restore the hydrology of the Everglades, including the Kissimmee River and Okeechobee Lake, in order to maintain these unique ecosystems (Sklar et al. 2005; LoSchiavo et al. 2013). The implementation plan is adaptive, benefiting from the increasing knowledge and the lessons learnt so far. A strong scientific framework allows for a clear setting of goals, an understanding of how the system works and an identification of the uncertainties and risks associated with the project (http://www.evergladesplan.org).

The *Four Major Rivers Restoration Project* in South Korea is a major water infrastructure project that addresses the environmental challenges faced by the Han, Nakdong, Geum and Yeongsam Rivers (Cha et al. 2011). The objectives include improved water storage and flood control, enhanced water quality and ecosystem health, provision of recreational space for local residents and improved cultural values of the rivers. It can primarily be considered an engineering project, rather than a restoration project, where natural processes will be mimicked and combined with constructed measures such as the building of dams and reservoirs. This project has provoked major opposition from both scientists and environmentalists because of the primary focus on hard engineering solutions and the distortion of scientific data for political purposes (Normile 2010). At the same time, this project is indented to form the nucleus for a national management programme to restore more than 10,000 km of local streams and rivers. At the same time, it is expected to stimulate the economy and create directly and indirectly up to 340,000 new jobs. The costs for this restoration project are estimated at USD 18 billion.

Other major restoration projects include the restoration of the Iraqi's marshes, once one of the largest and most valuable wetlands worldwide and identified as the historic garden Eden (Zahra Douabul 2012), restoring the balance of the Murray-Darling basin in Australia, or the manifold restoration work carried out across Europe, North America and Japan (Bernhardt et al. 2005; Nakamura et al. 2006). The European Water Framework Directive (WFD), for example, triggers major activities in the water sector in order to achieve a good ecological status or potential for its rivers, lakes and coastal zones. Indeed, a high proportion of the European river network must be restored in order to meet the ambitious goals set by the WFD. The restoration of the Rhine River, which already started much earlier than the implementation of the WFD, is a very good example for what may be achievable if the political will and the public pressure are high enough. After the Sandoz Accident in 1986, which released about 20 tons of pesticides and insecticides into the Rhine, immense financial resources have been invested to transform the Rhine from an open sewer to a river with a highly improved water quality and ecological state. However, the Rhine Programme also emphasis the limitations of restoration because the biological communities today are dominated by non-native species and thus very different from the communities that occurred before major pollution.

4.3 Discussion

We are facing a “pandemic array” (see www.gwsp.org) of transformations in the global water cycle, including fundamental changes in physical characteristics and biogeochemical and biological processes. Demographic and economic development increases the pressure on freshwaters and, together with an increasing frequency of floods and droughts, causes a dramatic increase in water stress and insecurity of water availability. At the same time, water security – the availability of freshwater in the eligible quantity and quality and at the right time – is a prerequisite for human wellbeing and ecosystem integrity.

Consequently, water security is one of the greatest challenges we are facing globally. Water shortage will require significant shifts in the way this precious resource will be managed. This is particularly the case if we want to manage freshwaters as a hybrid system, as both a medium for life and a resource for humanity. It is an interdisciplinary and cross-sectorial challenge linking economic, social, cultural and ecological systems. One of the proposed solutions is an engineering approach, although alternative ways to manage water as a resource and as a medium need to be established. However, in areas and during periods of water shortage, environmental damage and social consequences may receive less attention.

Megaprojects, such as major water engineering projects, are a sign of “high modernisms” (Scott 1998), an ideology that builds on self-confidence about technological progress. These projects are considered as a scaling-up of earlier successful projects and as a continuation of century-old practices (Forest and Forest 2012). Major infrastructure projects are believed to stimulate and guide economic development and to improve the living conditions for humans. At the same time, re-shaping the landscape is considered as a sign of progress as well as of regional and global power. In the Soviet Union, nuclear explosions were used to support major engineering projects, and their use had also been proposed for the NAWAPA project in North America. In this respect, Forest and Forest (2012) analysed the powerful role of visual rhetoric of water-transfer maps. Maps generalise and simplify, may ignore political boundaries, represent technology as an unproblematic approach and present water as a virtual entity. Therefore, we need to be very careful and responsible in using maps and visualisation tools in the decision making of major water engineering projects.

A fundamental problem with the planning and construction of large infrastructure projects is pervasive misinformation about costs, benefits and risks involved. A comprehensive analysis of large infrastructure projects in the UK and US (with emphasise on transportation infrastructure projects) demonstrated that in most cases the “unfittest proposals”, which underestimated costs and overestimated benefits, were approved (Flyvbjerg 2007). The causes of misinformation and risk are mainly cognitive and political biases such as optimism bias and strategic misrepresentation. This is also most likely true for water-related megaprojects, such as for large dam and IBT projects. Therefore, Lovallo and Kahnemann (2003) and Flyvbjerg (2007) recommend the use of a “reference-based forecasting” approach, taking an outside-view derived from information from a class of similar projects to reduce inaccuracy and bias. Even more important is accountability, both public-sector accountability through transparency and public control and private-sector accountability via competition and market control (Flyvbjerg et al. 2003). Indeed, there is hope that widespread mismanagement of large-infrastructure projects is decreasing because democratic governance is improving around the world.

However, many of the future mega-projects in the water sector are transboundary projects that are planned or under construction in less democratic, economically fragile and politically often unstable countries, governed by weak national and international water management organisations. In these countries international disputes over water issues are more likely, as clearly shown for the Central Asian water conflict, particularly between Kyrgyzstan and Uzbekistan over the Syrdarya water resources (e.g. Bernauer and Siegfried 2012). Solutions for megaprojects under these conditions may include the establishment of an outside international body for management, coordinated water resource management across political and sectoral borders, the application of a “reference-based forecasting” approach (see above), involvement of all stakeholders through a participatory approach, accountability and critical questioning. According to Flyvbjerg (2007), a key principal should be that the costs of making wrong forecasts should fall on those making the forecast.

Several of the listed megaprojects are so-called “zombie projects” (Gleick et al. 2014) because they were once proposed, killed for one reason or another and brought back to life, even if they are socially, politically, economically and environmentally unjustified. Indeed, they may resurrect when so-called “windows-of-opportunity” open, mainly as a consequence of major disasters, such as nuclear disasters, severe droughts, long-lasting water shortages, famines, etc. Many of these “zombie projects” are technically feasible; however, the associated costs are immense and may cause dramatic social, economic and environmental damages. In most cases, only the planning and construction costs are considered, and these costs are already systematically underestimated. The follow-up costs need to be covered mostly by the general public and may therefore harm the economy of entire countries.

A potential alternative concept is ecological engineering, which encompasses a variety of approaches for working with nature. This approach is often cheaper and more effective than hard engineering solutions at accomplishing specific goals and may include the restoration of floodplains, coastal zones and upland areas. The Mississippi Delta Repair Program, following hurricane Katarina, has been recently approved by the U.S. federal government. It applies a restoration rather than a hard engineering approach, and the benefits may be immense on the long-run considering the lower maintenance costs as well as the multiple services provided by the restored delta ecosystems. Similar approaches have been successfully applied in the lower Rhine River and the delta system in the Netherlands (e.g. providing more room for rivers instead of always higher dikes), as well as in Australia (see above). Many of the major future water infrastructure projects are planned in developing countries and emerging economies, where low-tech efforts rather than expensive engineering projects are required to meet the major challenges in the water sectors. Smart water investments in both developing and developed countries may include water-efficiency technologies, better wastewater treatment plants capable of producing high quality waters, improved piping and distribution systems, lower energy desalination systems, improved monitoring tools, low-water-using crop types and much more (Gleick et al. 2014).

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